

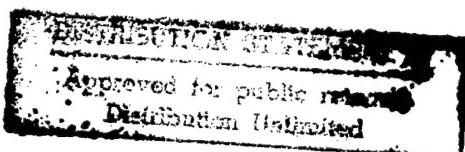
Progress Report  
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THE RESPONSE OF WIND RIPPLES TO LONG SURFACE WAVES

Mark Donelan  
Rosenstiel School of Marine and Atmospheric Science  
University of Miami  
4600 Rickenbacker Causeway  
Miami, FL 33149-1098  
Phone: (305) 361-4717, Fax: (305) 361-4701  
Email: mdonelan@rsmas.miami.edu

Vladimir N. Kudryavtsev  
Marine Hydrophysical Institute (MHI)  
Ukraine Academy of Sciences  
2 Kapitanskays Street  
Sevastpool 33500 Ukraine  
E-mail: odmi@alpha.mhi.iuf.net

Vladimir K. Makin  
Royal Netherlands Meteorological Institute (KNMI)  
Postbus 201  
3730 AE De Bilt  
The Netherlands  
E-mail: makin@knmi.nl

Vladimir E. Zakharov  
Department of Mathematics  
University of Arizona (UA)  
Tucson, Arizona USA 85721  
E-mail: zakharov@acms.arizona.edu



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## LONG-TERM GOALS

To develop an advanced physical model of the wind wave spectrum based on the Donelan and Pierson (1987) approach and accounting for the nonlinear processes in the capillary-gravity range consistent with existing analytic models of high-wavenumber spectra.

To construct a new version of the ABL model coupled with wind waves using an advanced wind wave spectrum model and the approach developed by Makin et al. (1995).

To build an unified model of the short wave modulations by long surface waves. This model originates from 2 and describes the reaction of the coupled system 'wind waves - ABL' in the presence of surface disturbances caused by long waves.

To verify the model results on the available radar data and the new data obtained from the MHI Black Sea Research platform.

## APPROACH

The final shape of the wave spectrum is defined by competition of the coupling with the air boundary layer, wave-wave interaction (distributing energy and momentum across the spectrum), and dissipation through wave breaking and viscosity. The main objective of the proposal is to develop a unified physical model of the short wave modulation by a longer wave of an arbitrary origin taking into account the coupling of wind waves and the air boundary layer (ABL), wave-wave interaction and dissipation.

Recently a few 'wind waves- ABL' coupled models have been proposed (e.g., Janssen, 1989; Chalikov and Makin, 1991; Makin et al., 1995). Kudryavtsev et al., (1996) have demonstrated that in such a coupled system a feed-back mechanism can emerge between the modulated wind waves and the near surface wind stress variations. This mechanism is responsible for the strong modulation of wind ripples by a long surface wave. A scheme of the feed-back action is the following: short waves affect the surface roughness, which determines the stress distribution. The stress in turn affects the short waves. The feed-back mechanism acts along with the wave-current and wave-wave interactions to produce the hydrodynamic modulation of wind ripples. In recent years the nonlinear interaction processes have been studied intensively; e.g. Zakharov (1992) and Pushkarev and Zakharov (1996).

The coupling between wind waves and the air flow is sensitive to the wave spectral form in the full wave-number range, in particular to the high wave-number part. At the same time, the active microwave sensor return depends on the short surface waves scattering through the Bragg resonance mechanism. Hence, an advanced physical model of the wind wave spectrum has to be constructed.

## WORK COMPLETED

The structure of an advanced model of the wind-wave spectrum has been proposed, including advective processes, wind input, dissipation (both viscous and white-capping), effects of parasitism between short waves and somewhat longer waves, and nonlinear interactions. A meeting of the P.I.s, held at the MHI, Sevastopol in early June, provided a forum for detailed exchanges of ideas and calculations. The work continues with the individual P.I.s concentrating on parts of the problem.

Measurements of wind-wave interaction and wave development were made by members of the staff of MHI, under the guidance of Vladimir Kudryavstev, on the Black Sea Research Tower in June, 1998.

## RESULTS

Further refinement of the rate of wave amplification by wind has resulted from laboratory measurements (Donelan, 1998) and numerical calculations (Makin, 1998). Calculations of the nonlinear interactions in the capillary-gravity range have been extended by Zakharov and Pushkarev, 1998. It was developed a new comfortable method for description of the nonlinear gravity waves interactions on deep water. A Boltzmann's collision term in the Hasselmann's equation was replaced by a nonlinear diffusive operator. The model equation has the same constants of motion as the exact equation and gives correct expressions for weak turbulent Kolmogorov spectra. A numerical simulation of the new model demonstrates a pretty good coincidence with the results of solution of the Hasselmann equation. The new model can be efficiently used in the study of physical mechanisms of air-sea interaction.

We studied numerically the weak turbulence of capillary waves on deep water. By a direct solution of the Euler equation in approximation of small angles we found that stationary spectra of capillary waves obey the Kolmogorov law  $K^{-19/4}$  which is exact solution of kinetic equation for waves. In situation when the turbulence is realized in finite-size tank there is completely new effect of "frozen" turbulence which could be realized at very low levels of the excitations of capillary waves. At "frozen" turbulence regime there is no energy flux from low wavenumbers of pumping toward high wavenumbers of damping.

### Publications:

1. V.E.Zakharov, A.N.Pushkarev. "Nonlinear diffusion approximation for kinetic equation for gravity waves", submitted for publication in Journal of Physical Oceanology.

2. A.N.Pushkarev, V.E.Zakharov. "Turbulence and capillary waves. Theory and numerical simulation", accepted for publication in *Physica D*.

The field tower measurements using wave following devices, optical slope gauges and x-band microwave radars have helped improve our understanding of the sensitivity and rapidity of response of capillary-gravity waves to wind forcing, dissipation, wave-wave interaction and modulation by longer waves.

#### IMPACT/APPLICATION

The impact of this work will be most immediately felt in the radar remote sensing community, where a complete model of the capillary-gravity waves, founded on sound physical principles and verified against field and laboratory data, is sorely needed. Other applications are in understanding and parameterizing such critical air-sea exchanges as gas transfer, momentum and heat transfer.

#### TRANSITIONS

None yet.

#### RELATED PROJECTS

The new Air-Sea Interaction Salt-water Tank (ASIST) facility, to be built on the campus of the Rosenstiel School of the University of Miami, will have the necessary delicate measuring capability to benefit from and further test the model being developed here.

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